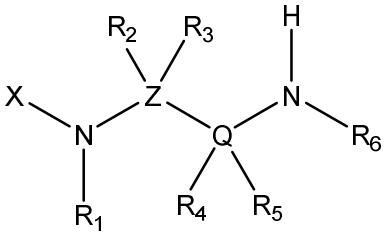
~~We claim:~~Claims

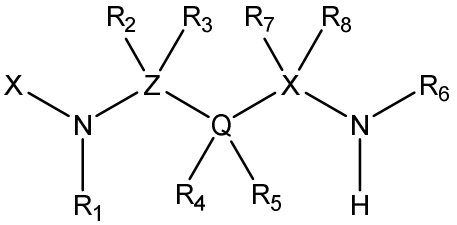
1. An adsorption material, comprising:

a metal–organic framework comprising a plurality of metal ions and a plurality of polytopic organic linkers, wherein each polytopic organic linker in the plurality of polytopic organic linker~~s~~ is connected to at least two metal ions ~~in~~ of the plurality of metal ions; and

a plurality of ligands, wherein each respective ligand in the plurality of ligands is amine appended to at least one metal ion in the plurality of metal ions of the metal–organic framework, each respective ligand in the plurality of ligands comprising:



or



wherein,

X is a metal ion of the metal–organic framework,

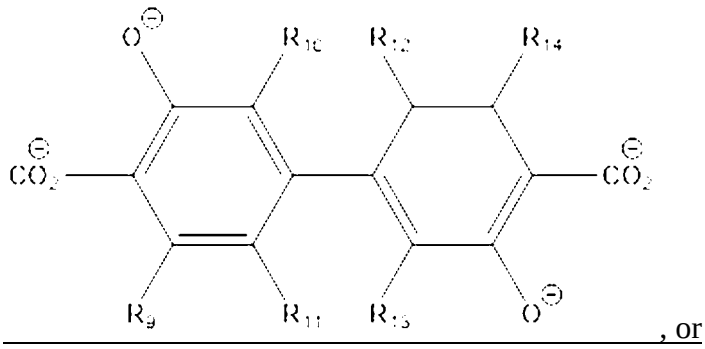
Z is carbon, silicon, germanium, sulfur, or selenium,

Q is carbon, silicon, germanium, sulfur, or selenium,

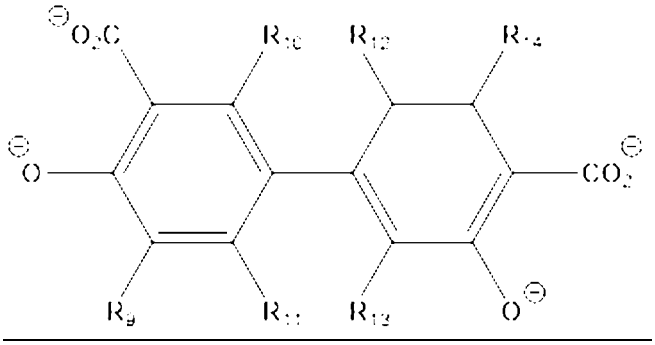
R_1, R_2, R_3, R_4, R_5, R_7, and R_8 are each independently selected from H, halogen, substituted or unsubstituted alkyl, substituted or unsubstituted heteroalkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl, or substituted or unsubstituted heterocycloalkyl, and

R_6 is substituted or unsubstituted alkyl, substituted or unsubstituted heteroalkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl, or substituted or unsubstituted heterocycloalkyl, wherein R_6 comprises ~~comprising~~ at least three non-hydrogen atoms,

each polytopic organic linker in the plurality of polytopic organic linkers has the formula:



, or



and wherein,

R_9, R_{10}, R_{11}, R_{12}, R_{13} and R_{14} are each independently selected from H, halogen, hydroxyl, methyl, and halogen substituted methyl.

2. The adsorption material of claim 1, wherein each metal ion (X) in the plurality of metal ions is Mg, Ca, Mn, Cr, Fe, Co, Ni, Cu, or Zn.

3. The adsorption material of claim 1 ~~or 2~~, wherein R_6 is substituted or unsubstituted alkyl having between three and ten carbon atoms.

4. The adsorption material of claim 1 ~~or 2~~, wherein R_6 is an *n*-alkane with between three and ten carbon atoms.

5. The adsorption material of claim 4, wherein R_6 is propyl, butyl, pentyl, hexyl, or heptyl.

6. The adsorption material of claim 1 ~~or 2~~, wherein R_6 is a branched-chain alkane.

7. The adsorption material of claim 1 ~~or 2~~, wherein R_6 is a substituted or unsubstituted heterocycloalkyl.

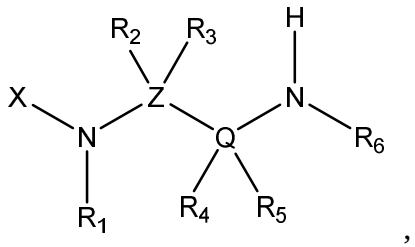
8. The adsorption material of claim 1 ~~or 2~~, wherein R_6 is a cycloalkane.

9. The adsorption material of claim 1 ~~or 2~~, wherein R_6 is substituted or unsubstituted cyclopropane, cyclobutane, cylopentane, or cyclohexane.

10. The adsorption material of ~~any one of claims 1-9~~ claim 1, wherein R_1 is hydrogen.

11. The adsorption material of ~~any one of claims 1-10~~ claim 1, wherein

each respective ligand in the plurality of ligands comprises:



,

R_2, R_3, R_4, and R_5 are each hydrogen, and

Z and Q are each carbon.

12. The adsorption material of ~~any one of claims 1 or 3-11~~ claim 1, wherein each metal ion (X) in the plurality of metal ions is Mg.

13. The adsorption material of claim 1, wherein each ligand in the plurality of ligands is *N*-(*n*-heptyl)ethylenediamine.

~~14. The adsorption material of any one of claims 1, 2, 12, or 13, wherein the polytopic organic linker is 4,4′-dioxidobiphenyl-3,3′-dicarboxylate (dobpdc^{4-}).~~

~~15. The adsorption material of any one of claims 1, 2, 12, or 13, wherein the polytopic organic linker is 4,4"-dioxido-[1,1':4',1"-terphenyl]-3,3"-dicarboxylate (dotpdc^{4-}).~~

~~16~~14. The adsorption material of ~~any one of claims 1, 2, 12, or 13~~ claim 1, wherein the polytopic organic linker is 3,3'-dioxidobiphenyl-4,4′-dicarboxylate (para-carboxylate-dobpdc^{4-}).

~~17~~15. The adsorption material of ~~any one of claims 1-16~~ claim 1, wherein the adsorption material exhibits a single CO_2 adsorption step upon CO_2 adsorption.

~~18~~16. The adsorption material of ~~any one of claims 1-17~~ claim 1, wherein the adsorption material exhibits a single CO_2 desorption step upon CO_2 desorption.

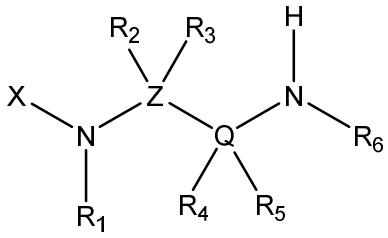
~~19~~17. The adsorption material of claim 1, wherein the adsorption material has a 77 K N_2 Brunauer-Emmett-Teller (BET) surface area of at least 3050 m^2/g.

~~20~~18. The adsorption material of claim 1, wherein the adsorption material has a Langmuir surface area of at least 5800 m^2/g.

~~21~~19. The adsorption material of claim 1, wherein the crystallographic density of the adsorption material is between 0.4 g/cm^3 and 1.2 g/cm^3.

~~22~~20. The adsorption material of claim 1, wherein

each respective ligand in the plurality of ligands comprises:

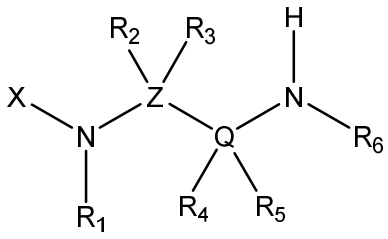


, and

R_6 has a molecular weight of 44 g/mol or greater.

~~23~~21. The adsorption material of claim 1, wherein

each respective ligand in the plurality of ligands comprises:

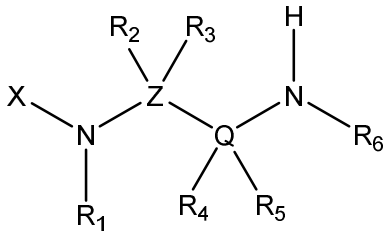


, and

R_6 has a molecular weight of 58 g/mol or greater.

~~24~~22. The adsorption material of claim 1, wherein

each respective ligand in the plurality of ligands comprises:

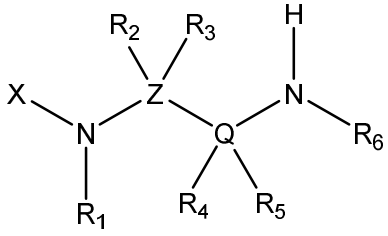


, and

R_6 has a molecular weight of 72 g/mol or greater.

~~25~~23. The adsorption material of claim 1, wherein

each respective ligand in the plurality of ligands comprises:

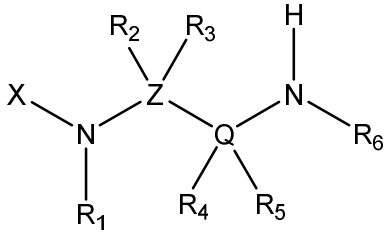


, and

R_6 has a molecular weight of 86 g/mol or greater.

~~26~~24. The adsorption material of claim 1, wherein

each respective ligand in the plurality of ligands comprises:

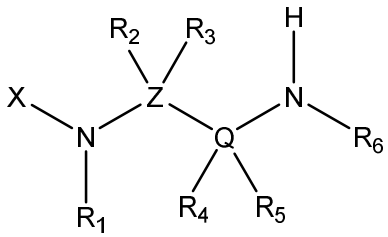


, and

R_6 has a molecular weight of between 72 g/mol and 500 g/mol.

~~27~~25. The adsorption material of claim 1, wherein

each respective ligand in the plurality of ligands comprises:

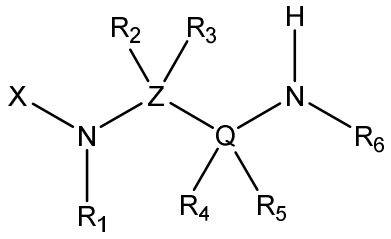


, and

R_6 has a molecular weight of between 58g/mol and 400 g/mol.

~~28~~26. The adsorption material of claim 1, wherein

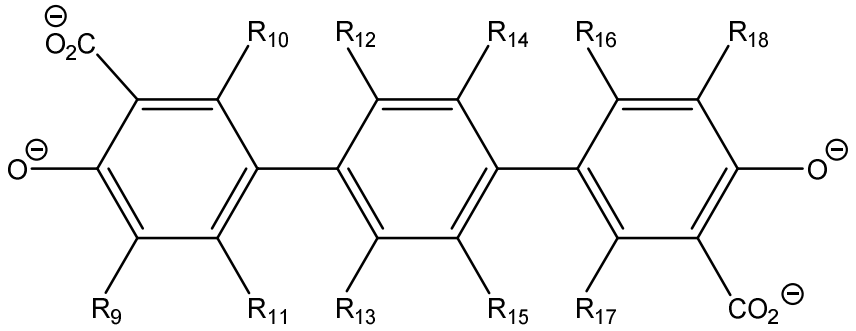
each respective ligand in the plurality of ligands comprises:



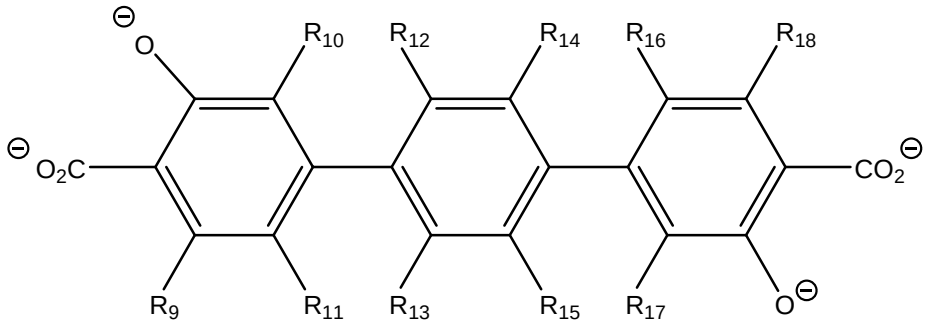
, and

R_6 has a molecular weight of between 44 g/mol and 300 g/mol.

~~29. The adsorption material of any one of claims 1, 2, 12, 13, or 19-28 wherein the polytopic organic linker has the formula:~~

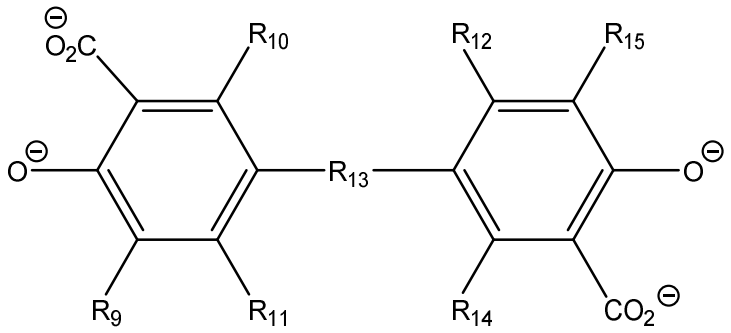


~~or~~

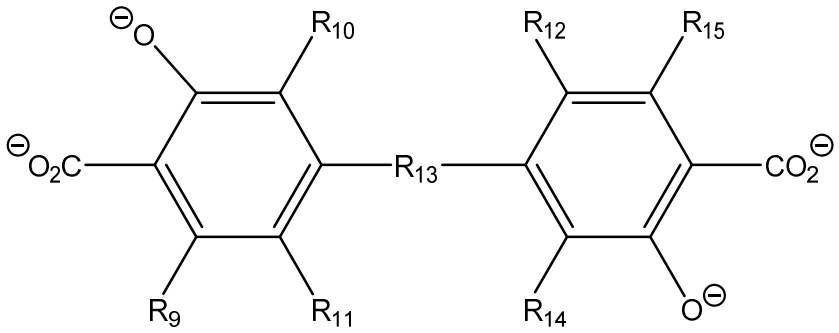


~~wherein R_9, R_{10}, R_{11}, R_{12}, R_{13}, R_{14}, R_{15}, R_{16}, R_{17}, and R_{18} are each independently selected from H, halogen, hydroxyl, methyl, and halogen substituted methyl.~~

~~30. The adsorption material of any one of claims 1, 2, 12, 13, or 19-28 wherein the polytopic organic linker has the formula:~~



~~or~~

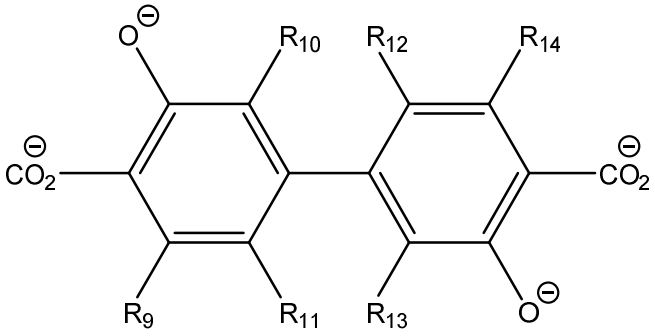


~~wherein,~~

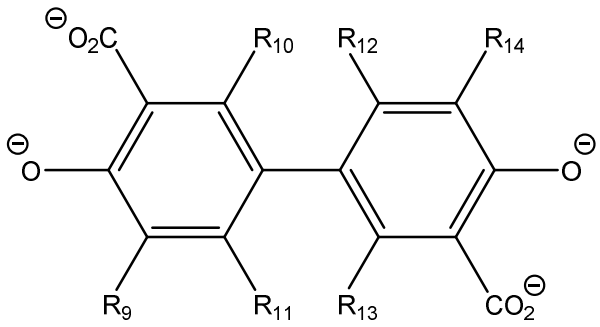
~~R_9, R_{10}, R_{11}, R_{12}, R_{14} and R_{15} are each independently selected from H, halogen, hydroxyl, methyl, and halogen substituted methyl, and~~

~~R_{13} is selected from substituted or unsubstituted aryl, vinyl, alkynyl, and substituted or unsubstituted heteroaryl.~~

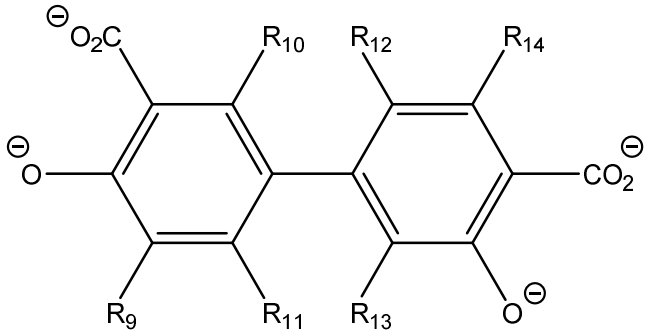
~~31. The adsorption material of any one of claims 1, 2, 12, 13, or 19-28, wherein the polytopic organic linker has the formula:~~



~~,~~



, or



wherein,

R_9, R_{10}, R_{11}, R_{12}, R_{13} and R_{14} are each independently selected from H, halogen, hydroxyl, methyl, and halogen substituted methyl.

32. A method for abating CO_2 from a flue gas, the method comprising:

(a) contacting the flue gas with the adsorption material of any one of claims 1-31 to reversibly adsorb CO_2 from the flue gas thereby generating an adsorption material enriched for CO_2; and

(b) thermally stripping a major portion of the CO_2 from the adsorption material enriched for CO_2 using a temperature swing adsorption method or a vacuum swing adsorption method.

33. A method for removing CO_2 from a biogas, the method comprising contacting the biogas with the adsorption material of any one of claims 1-31 to reversibly adsorb CO_2 from the biogas the contacting thereby generating an adsorption material enriched for CO_2 and a residual gas that is greater than 98 percent pure methane.

34. The method of claim 33, the method further comprising thermally stripping a major portion of the CO_2 from the adsorption material enriched for CO_2 using a temperature swing adsorption method or a vacuum swing adsorption method.

~~35. A method of sequestering carbon dioxide produced by a source, comprising exposing the carbon dioxide to the adsorption material of any one of claims 1-31, whereby the carbon dioxide is reversibly sequestered into the adsorption material.~~

~~36. The method of claim 35, the method further comprising regenerating the adsorption material enriched for CO_2 using a temperature swing adsorption method, vacuum swing adsorption method, a pressure swing adsorption method, a concentration swing adsorption method, or a combination thereof.~~